Connecting VET teachers to Agriculture 4.0

ICT skill demands of the agricultural labour market

Comparative analysis and summary

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1 INTRODUCTION

Information and communication technologies are currently affecting all sectors of human activity. This is also the case in agriculture, forestry, water management, food industry, rural development, etc. According to the FAO, it has been demonstrated that the ability of the agricultural community to connect to knowledge databanks, networks and institutions through information and communication technologies will substantially improve its productivity. Such a model is generally referred to as e-Agriculture. The term e-Agriculture is therefore considered to be an emerging field geared to enhance agricultural and rural development through improved information and communication processes. In this context, information and communication technologies are used as an umbrella term covering all information and communication technologies, including devices, networks, mobile phones, services and applications. These range from innovative technologies on the Internet, sensors, agricultural machines and satellites to other existing utilities such as telephones, computers, TVs, radios, etc. ICT thus includes any device, tool or application that allows data exchange or collection via iteration and transmission , where ICT is an overarching concept that includes everything from a mobile phone through electronic payments to satellite imagery.

More specifically, e-Agriculture includes conceptualization, design, development, assessment and application of innovative ways of using ICT in a rural area with a primary focus on agriculture. The setting of standards, methods and tools, as well as the development of individual and institutional capacities and political support, are key components of e-Agriculture (FAO, 2016, FAO, 2017).

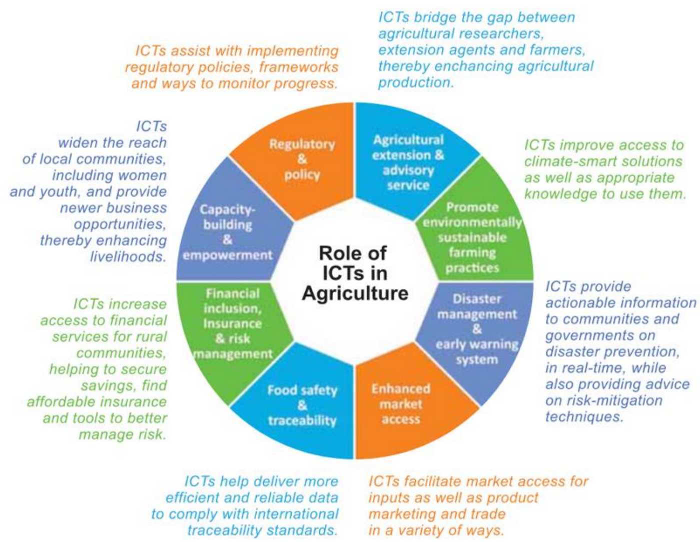

Figure 1. Role of ICT in agriculture (FAO, 2016).

One of the key prerequisites for efficient use of information and communication technologies in the agricultural sector is the construction of high-speed networks and, in particular, the availability of high-speed Internet access from mobile devices. This applies not only to mobile phones but more so to various specialized devices that are usable in field conditions.

Although the various ICT activities and initiatives that bridge the digital divide are being widespread around the world, the World Summit of the Information Society in 2003 and 2005 established an e-Agriculture community where people from around the world exchange information, ideas and resources for the use of ICT in sustainable agriculture and rural development.

2 PRECISION AGRICULTURE

Precision agriculture is the concept of modern agriculture management using digital technologies for monitoring and optimizing production processes in agriculture. The term precision agriculture covers many different areas and various technologies that can be utilized to optimize costs and productivity of agricultural production. Precision agriculture uses satellite navigation and navigation positioning systems, as well as a number of other technologies. These include: automatic control, prescribed trajectories, automatic vehicle rotation, etc.

2.1 NAVIGATION AND AUTOMATIC STEERING

One of the numerous digital technologies used in PA is the automated steering of the tractor using GNSS. This technology can be applied to several basic types of technical equipment (listed sequentially according to the history of deployment and technological demands):

- optical indication of compliance with the desired motion trajectory (driver assistance)
- steering support (support for older tractor types) - this system is an intermediate stage because it eliminates the influence of the driver's error in the desired trajectory but does not achieve top reaction accuracy and speed due to the missing information about the current wheel angle
- automatic steering as part of the tractor system (automatic driving)
- Controlled Traffic - full control of the operation of agricultural machinery on land

2.2 GNSS

GNSS (Global Navigation Satellite System) systems

To simplify, satellite positioning systems can be described as a passive satellite radio-frequency distance measuring systems – meaning the satellite continuously passively broadcast a time-stamped radio signal and based on the time-stamp and known location (orbital trajectory tracking parameters that are also broadcasted) of at least 3 satellites, the receiver calculates its own position.

There are several key systems currently in use:

GPS

GPS is military navigation system developed by USA, sometimes referred to as its official name NAVSTAR GPS (Navigation Signal Timing And Ranging Global Positioning System). It is fully operational since July 17, 1995. For civilian use, the full-featured signal is available from 2000. The space segment consists of 24 satellites evenly distributed over six orbital planes.

GLONASS

GLONASS is a Russian military navigation system, developed since 1976, in operation in 2011. As with GPS, the complete GLONASS constellation consists of 24 satellites, 21 of which will be in operation and 3 will be backup (each in one of the three orbital planes).

EGNOS

System EGNOS (European Geostationary Navigation Overlay Service) is a European project that provides GPS signal correction in the form of a differential signal. Corrections are provided for Europe and are important for eliminating the errors inherent to the transmitted signals. Differential signal processing in the GNSS receiver results in more accurate positioning.

Galileo

Galileo is the European civilian navigation system, which is currently undergoing operational testing. The Galileo navigation system is a planned autonomous European Global Positioning System (GPS), which should be similar to the US Navstar GPS system and the Russian GLONASS system. Its construction is provided by the European Union (EU) represented by the European Commission (EC) and the European Space Agency (ESA). GNSS Galileo should have been operational from 2010. According to new plans, the release is scheduled for year 2018.

2.3 RTK

The navigation systems themselves (with free access) do not achieve the precision required for use in Precision Agriculture. There are different ways of correct the positioning. Aside from proprietary systems supplied by machine manufacturers, the RTK system is the most important, since it makes possible to refine the position with a minimum deviation, so that it complies with the precision required by autopilots.

The availability of the correction signal in European countries is ensured as follows:

- by a network built as part of the EUPOS European project, an initiative to create a unified DGNSS infrastructure, in Central and Eastern Europe primarily for geodetic needs.
- by networks operated by multinational commercial operators – mostly geodetic companies that have built "pan-European networks" like LEICA - SmartNet, Topcon - TopNETlive network, Trimble - Trimble VRS network.
- by networks built by local commercial entities

2.4 EXPECTED ENVIRONMENTAL BENEFITS FROM PRECISION AGRICULTURE

Automatic steering control reduces human errors and also contributes to efficient soil and parcel management. For example, automated vehicle turning could save between 2% and 10% of fuel consumption.

In a survey of large farms in North Dakota, USA, Bora et al. (2012) found that 34% of farms using GPS guidance systems had shortened machine utilization times and fuel consumption by up to 6.04%, respectively 6.32%. 27% of farms using automatic steering further reduced machine usage time by 5.75% and fuel consumption by 5.33%. This is where cost savings in terms of fuel consumption and carbon footprint reduction are achieved.

According to prof. Godwin (2015) and his long-term research, it is possible to reduce costs by up to 35 EUR / ha. Another studies speak about up to 6.32% of fuel savings (Bora et al., 2012), or about a significant reduction in overlapping work operations (Macak et al., 2011, Kviz et al., 2104, Reckleben and Noack, 2012) or about reducing herbicide usage by up to 50% (Perez-Ruiz et al., 2013) using the autonomous management. This for example, assuming the fuel consumption is between 100,000-500,000 liters of diesel fuel on farms (which is the range for farms that manage most of the arable land), represents a significant economic saving that is reflected in the farm's profit. Saving fuel and chemicals also has a significant impact on the state of the environment. Reducing their consumption will result in a significant reduction in the environmental burden that agriculture produces. At the same time, it will support accurate and correct implantation under the Nitrates Directive and the WFD (Water Framework Directive).

3 REMOTE SENSING

The management of state's territory requires very good information background for decision-making, which can be supported by remote sensing. For planning activities, comparing the current state with the past, predicting weather behavior, or monitoring human influence, it is necessary to have a high-quality data base that can analyze the development of the monitored issue over time. Data (not just images) can be captured in a variety of ways: aerial, satellite, and unmanned vehicles (drones). Satellite technologies, and the European Copernicus program and its data sets in particular, bring a whole new level of spatial and temporal resolution. This concerns both current crop health status and long-term trends. A short period of data acquisition guarantees a statistically higher probability of obtaining data unobstructed by clouds for each monitored phenological phase.

3.1 PROGRAM COPERNICUS

The line of Sentinel satellites consists of several types of satellites, typically discharged in pairs to provide faster data acquisition. At present, the satellites of the first two missions are active and the third mission is in trial operation. Other satellites are in preparation, and their sending into orbit is a matter of next few years. Every Earth exploration mission must also provide ground operations in addition to the satellites. It is responsible for managing satellites, receiving and processing data, and for making data available.

Each Sentinel mission produces a large amount of data that needs to be processed into a usable form. Typically, data is being cleaned and calibrated. The raw signal is corrected by spectrum corrections. Each data set represents image of a particular part of surface area of the Earth. Data sets are downloadable and usable free of charge. However, it is necessary to count on large data production, especially when it is constantly updated. The data is available through Sentinel and Landsat web sites. The basic idea is slightly different, given by local customs and views on open data. The data is available in a form that allows automatic downloading and subsequent machine processing. Everything is just a question of the ability of the subject who wants to explore and exploit the data. All data sets are available through https://scihub.copernicus.eu/ - access is for registered users only, but registration is very easy and access to the data is free. The program has set points of functionality which are being progressively completed.

There is an online interface called Open Hub, which is available through a browser and requires registration to access the data (respecting the terms and conditions of course). The graphical interface is very good - simple and easy to use, and provides convenient use of the data sets.

The API Hub is designed for automated download of data sets. It does not have a graphical interface and is made available on the basis of standardized reports. API Hub access is currently available for all SciHub registered users. The only limitation is in write-through of login credentials.

Data from the Landsat satellite system is available at the website `https://landsat.gsfc.nasa.gov/data/`.

4 ICT-AGRI

According to the European Commission and Eurostat (EC, 2017), GDP in the EU in 2016 was 14 820 936 million EUR, with an average GDP per capita of 29 000 EUR and an average growth of 1,9%. Trade in agricultural produce between EU countries and other countries amounted to 131 126 million EUR (exports) and 112 189 million EUR (imports). Domestic intra-EU trade in agricultural production amounted to 349 940 million EUR for exports and 346 924 million EUR for imports.

The European Commission is funding the ICT-AGRI program under the Seventh Framework Program for Research on ERA-NET. The objective of the ERA-NET program is to develop and strengthen the European research area by facilitating practical initiatives to coordinate regional, national and European research programs in specific areas. The ICT-AGRI-1 program started on 1 May 2009 and ran for 65 months until 30 September 2014. The ICT-AGRI-2 project started on 1 January 2014 and is scheduled for 4 years until the end of 2017.

The main objective of the ICT-AGRI program is to strengthen European research in the diverse field of precision agriculture and to develop a joint European research agenda on ICT and robotics in agriculture and to monitor the challenges of funding from the national research programs of the participating countries. The aim is to gather fragmented human and financial resources to improve both the efficiency and effectiveness of European research efforts.

The specific objectives of ERA-NET ICT-AGRI are:

- Mapping and analysis of existing research and future needs
- Developing tools and procedures for transnational funding
- Developing a strategic transnational research agenda and programs
- Establishing and maintaining international co-operation and networks

As mentioned in the chapter on the Digital Agenda for Europe, the Digital Single Market (DSM) is one of the main priorities of the "Juncker Commission". One of the objectives of the DSM package is to close the digital divide between urban and rural areas and provide fast (ultra-fast broadband) internet access throughout the EU by 2020.

5 STATE OF AGRICULTURE IN SELECTED COUNTRIES

5.1 HUNGARY

5.1.1 GENERAL OVERVIEW OF HUNGARIAN AGRICULTURAL SECTOR

Overall, the agricultural conditions in Hungary are above average. Compared to other European countries, terrain conditions are favorable for agriculture. The proportion of lowlands is high compared to all areas, only few countries have a better position in this respect (such as Denmark). Hungary lies on the border between the dry and wet continental climate. Because of this, the precipitation conditions are slightly worse than for countries further west and the drought periods are more frequent and longer. Approximately half of the country's land is cultivated by arable land.

Agriculture is a traditionally important sector in the Hungarian economy, as the country has favorable conditions for many types of farming, and about 70 percent of the land area is suitable for agricultural production. Despite these facts, the share of agriculture in the economy has been decreasing. However, Hungary's around 4% agriculture value added is still the third highest among EU-countries, and the sector employs around 5% percent of the work force. Overall agriculture has contributed about 3.8% in gross domestic product (GDP) output in 2016.

5.1.2 FARMING IN HUNGARY

In 2016, 9,000 agricultural corporations carried out agricultural activities in Hungary, 68% of them, 6120 were specialized crop farmers, while the number of individual farms was 416,000 and half were crop farmers. The average farm size of the corporate farms was 253 hectares, and the average size of the farms used by individual farmers was 7.6 hectares. Hungary's land area of 6 million hectares is 4.5 million hectares of agricultural land, and individual farms account for 58 % of the land.

The sowing structure has not changed substantially in recent years. The proportion of cereals in the field sowing structure was 60% in 2016. The combined area of wheat and maize together accounted for almost half of the arable land. The proportion of oily plants in the last years has been between 20-24%. In 2016 the ratio of sunflower was 15%, rape was 5.9%. The combined ratio of these two industrial plants in the 2006 sowing structure was 16%, while in 2016 it was 22%.

The livestock sector has been growing steadily since 2011, with farmers holding 2.1% more livestock in 2016 than in the previous year and 20% more than five years earlier. Of the total 838,000 livestock, 379,000 cows increased by 3.2% in one year. 60% of the stock is held by economic organizations, 40% is considered by private farms, this distribution has not changed in recent years. The domestic pig population was 2.9 million on 1 December 2016, 7.6% less than a year earlier. Domestic poultry farms declined slightly (by 0.6%) in 2016, with 40.1 million animals in December.

5.1.3 ICT INFRASTRUCTURE AND PRECISION FARMING IN HUNGARY

Internet usage is high among the population, and the majority of households have an internet subscription. The country is lagging behind in terms of mobile broadband subscription, mainly caused by the affordability of the service. The Government Online Service index is higher than the average of the region. The Network Readiness Index value is under the average of Central and Eastern European countries.

The economic benefits of ICT tools in the national agricultural sector are currently sparsely used in Hungary. Existing systems work in isolation, linked by human channels, resulting in a significant loss of data and data quality. Information technologies that are purchased through grant programs are standard equipment, but they provide real economic benefits only with proper integration.

The main obstacle to the spread of IT solutions in domestic agriculture is the lack of preparedness, skills and attitudes of human resources. Most of the users do not currently have the skills and skills to use IT systems at user level. There is very little demand for the purchase and use of new systems. Lack of skills also characterizes advisory networks, so the innovation chain does not reach the level of the producer. It should be noted that most of the leaders and decision-makers of state and chamber organizations for producers do not know the available options.

IT applications supporting agricultural production can be divided into five large groups in Hungary:

1. production-support applications that assist automated or semi-automated interventions directly to certain activities in agricultural production;
2. farm level production management systems to assist decision-making and to integrate individual processes at producer level;
3. supply chain integration systems that support the process of integration from both the producers and the integrators, are linked to producer-level systems as needed;
4. professional back-end systems that provide background data for systems run by producers and integrators and collect and analyze data generated at producer level;
5. e-government back-end systems that support processes between administration and producers (e.g. request and claims for grants and subsidies, supply chain controls).

Precise crop production started in Hungary in the first half of the 2000s, however, technology is still less widespread despite the increase in the number of farmers practicing location specific applications has accelerated in recent years. According to a 2015 survey, only half of arable crop growers have heard of precision farming, but this proportion depends on the size of the farm. Among decision makers of over 500 hectares 88%, in medium-sized farms between 100 and 500 hectares 67%, while in small farms under 100 hectares only one-third have heard about precision farming.

5.2 MACEDONIA

5.2.1 GENERAL OVERVIEW OF MACEDONIAN AGRICULTURAL SECTOR

The agricultural sector in Macedonia is third biggest GDP contributor right behind the services and industry with 12% contribution. Altogether with the food processing industry contribute 18% from the total GDP. According to SSO (2017), 1,263 million ha or 49% of total area is agricultural land (cultivated land and pastures), 38% are under forests while about 13% are water and other surfaces. Cultivated land represented approximately 514.000 ha or approximately 41% of total agricultural land, while the remaining 59% is categorized as pastures.

Around half of the total exported and imported agro-food and fishery products' value was realized with the EU-28 (i.e 48,7% share on the export and 49,5% share on the import side) (SSO, 2017). The most important Macedonian agro-food export products to the EU-28 in 2016 were: un-manufactured tobacco (share of 28,9% of the total export), biscuits and wafers (10,8%), wine (10%), other vegetables prepared or preserved (6,7% of total export), lamb meat (5,1%), vegetables (uncooked or cooked by steaming or boiling in water), frozen (4,2%) and other vegetables, fresh or chilled (4,5%) (SSO, 2017).

Republic of Macedonia is net exporter of wine as a strategic export product for the country. In terms of the overall export value of agricultural products, wine export holds the second position right after tobacco. The crop production structure is broken down into five main groups: production of cereals, industrial, forage, horticultural crops, orchards and vineyards. The vegetable production is one of the most important and traditional agriculture sectors which cultivates on 53.000 ha or 19% of total sown area.

5.2.2 FARMING IN MACEDONIA

The total workforce of Macedonia employed in agriculture, forestry, fishing and hunting has dropped from 475956 people in 2006 to 431966 in 2015 (SSO, 2017). The employment in the agriculture sector out of total country's employment in 2000 was 22% comparing with 17.3% in 2014. In general, family-farm structures give way to larger, monoculture farm operations, the number of young people with a comprehensive understanding of farming has seen a substantial decline.

Small-scale agricultural holdings dominated agricultural production both before and after the privatization process in the 1990s. The farm structure survey from 2013 reported 170 885 agricultural holdings utilizing 315 863 ha of agricultural area, with an average farm size of 1.85 ha (SSO, 2013). Long-term strategy for agriculture and rural development based on preference for subsiding production and quantity makes Macedonian farmers (especially those 0.1% large-scale agri- food companies) maintain "the socialist habit" of mass and managed production (Trendov, 2017).

Productivity in agricultural production in the Republic of Macedonia is lower in comparison with EU countries. Multiple analyses show that productivity efficiency has the highest correlation depending on the application of technical and technological solutions or the development research activities. Therefore we believe that the productivity of the agricultural sector in the Republic of Macedonia can be increased through the adoption of new technologies of crop production and livestock farming.

5.2.3 ICT INFRASTRUCTURE AND PRECISION FARMING IN MACEDONIA

Telecommunication services have developed very fast over the past two decades. This growth was primarily driven by wireless technologies and liberalization of telecommunications markets, which have enabled faster and less costly network rollout. With the rapid development of mobile telephony and the global expansion of the Internet, information and communication technologies are increasingly recognized as essential tools of development. Mobile communications have a particularly important impact in rural areas. The mobility, ease of use, flexible deployment, and relatively low and declining rollout costs of wireless technologies enable them to reach rural populations with low levels of income and literacy.

An analysis of mobile subscriptions in western Balkan countries indicates that mobile phones are widely used and can be good base to approach farmers in rural areas. Farmers can easily use mobile applications in agriculture, gain fast and relevant information through social media or internet via smart phones.

The survey results from Macedonia (FACE, 2017) showed that, beside the conventional and broadly accepted ICT tools such as radio and TV (98%), farmers have shown significant knowledge in using ICT tools such as smartphones (55%), computers (70%), and internet (60%). This can be considered as noteworthy indication that there is an essential base for introduction of agricultural technologies based on ICT. However, it seems that for many farmers, the digital revolution does not live up to its promises. The reasons for this uptake gap are well-known: a lacking broadband internet in many rural areas, high purchase costs of technologies such as variable-rate systems and low generational renewal in farming.

Farmers in Macedonia have very little awareness and knowledge about more advanced technologies based on ICT such as automated systems, GPS or GIS systems and devices for precision agriculture. Teachers of agricultural techniques are therefore faced with the dual challenges of accommodating students with lower farming literacy, while allowing them to catch up with the digital revolution. This requires new methods, and, possibly, stronger public support. Younger generation of farmers are more agile and eager to gain more knowledge about farming. Younger farmers are frequently attending trainings or educational events to gain knowledge. The best way of capturing a broader audience of farmers is through pilot/demonstration sites/fields where latest modern achievements in the agri-food sector will be presented. Such events have to be organized by the universities, extension services and companies providing solutions through precision farming technologies.

6 SURVEY

A survey was conducted among farmers from selected countries. Apart from getting basic background information about the respondents (type of farm, size, number of employees etc.), the main goal was to ascertain the level of knowledge about ICT tools and precision farming methods among the farmers and its level of utilization. Therefore the survey was separated into three sections:

1. Base data – type of enterprise, number of employees, area of arable land etc.
2. ICT in agriculture– e-government, software tools for reporting, e-agriculture, data analysis, forecasting etc.
3. Precision farming – automatic steering, navigation, RTK, sensors, GIS

The full list of questions and analysis of the survey is far to detail for the scope of this summary, therefore the following overview only includes certain important results and aspects for each country.

6.1 SURVEY RESULTS IN HUNGARY

Participants from Hungary were mostly from small to medium-sized enterprises (53% of respondents), while the majority had less than 10 employees (70%). The main sector of activity was a combination of plant production, livestock farming and horticulture. Most participants were familiar with various ICT technologies while only small portion (5%) reported having difficulties using ICT in their day-to-day work. However, 31% of users replied that they are facing partial difficulties with ICT. Vast majority (80%) replied that they think they are not using ICT technologies to their fullest potential. Half of the participant replied they are considering subcontracting an outside ICT expert to help manage and exploit the advantages of e-agriculture.

Most of participating companies answered that they would support a special training in terms of ICT for one or more of their employees. However, they also expressed a concern regarding the costs of such training. The issue is that if they were to finance a special education of their employees themselves, the return of such investment is not guaranteed.

From the viewpoint of precision agriculture, most respondents are familiar with the term and even utilize some technique of precision agriculture already – automated steering (39%), sensors (71%), robotics (76%). The lowest scores from the various precision agriculture technologies was obtained by remote sensing and geographic information systems, where only 14% (or 7% respectively) of companies fully utilize these technologies.

Overall, the result of the questionnaire fully supports the fact that the vast majority of agricultural producers currently have heard about precision technologies but for the most part are not using any, or only using a selected few.

Most of Hungarian farms of all-sizes encounter access to and use of ICT tools (land surveying, soil and leaf testing, use of e-Government tools, reports, data submissions, registers, etc.), while the use of precision tools is more typical of larger farms. Most of the farmers shown a positive attitude towards ICT tools, they are open to new technologies and are eager to obtain more knowledge in the area.

6.2 SURVEY RESULTS IN MACEDONIA

The overwhelming majority of participants in Macedonia were from small-to-medium enterprises (91%), however approximately half (55%) responded they employ between 10 and 100 workers. The main sectors of activity were plant production, animal breeding and commerce. Vast majority (over 90%) are familiar with at least some ICT related terms and believe that utilizing ICT technologies has benefits in helping day-to-day work and administration, while only half recognized the potential of ICT for cost reduction and revenue increase. 64% of respondents replied they do not have any particular issues utilizing ICT, however only 18% replied they feel they are utilizing ICT to its full potential.

As far as precision agriculture is concerned the results show poor level of utilization of these tools in practice. While many respondents replied, they know about certain aspects of precision farming – automated steering (50%), sensors (44%), robotics (25%), remote sensing (36%), GIS (43%), the overall number of companies that actually currently utilize precision agriculture methods is significantly lower (zero in some cases such as remote sensing and GIS).

The findings of the survey are substantial to the further research in the field of utilization of ICT tools in agriculture in Macedonia. We find the survey results satisfactory in relation to the survey goals, as a much clearer vision of the situation of utilization of ICT tools in Macedonia is now available. The findings of the survey are a clear indicator that companies in Macedonia use ICT tools, but the level of utilization is still low especially when precision farming is concerned and there is still a lot of room for further improvement.

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